All-Optical Switch Based on the Local Nonlinear Plasmonic Mach-Zehnder Interferometer Waveguides

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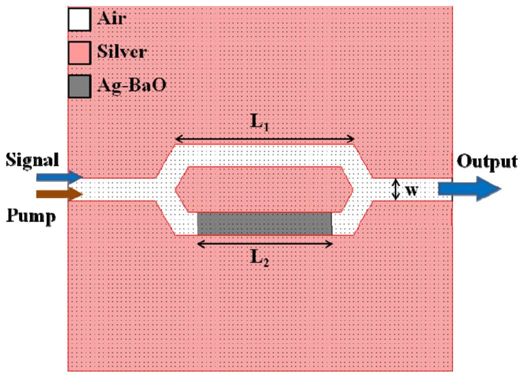
***Abstract* –A new all-optical switch based on the local nonlinear metal-insulator-metal (MIM) plasmonic Mach-Zehnder interferometer (MZI) waveguides was proposed. We used the finite-difference time-domain (FDTD) method to simulate the proposed structure. The numerical show that the proposed local nonlinear MIM plasmonic MZI waveguide structure could really function as an all-optical switch.**

I. INTRODUCTION

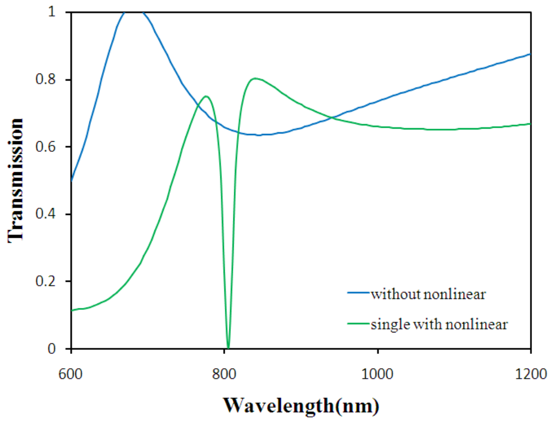
In recent years, the development of optical components is growing prosperity. Accordingly, all-optical signal processing and control also becomes important. All-optical signal processing in integrated photonic circuits and its applications in optical computing and communications require the ability to control light with light [1]. Therefore, all-optical switching devices and waveguide with nonlinear Kerr effect logic gate has begun to attract attention. Several all-optical switching and logic devices using optical nonlinearity have ever been proposed and implemented [2-3]. Most of the conventional all-optical devices are based on uniformly nonlinear structure. In optical waveguide structure of uniform nonlinearity, several interesting optical properties have shown, however, there are still more attractive propagation characteristics in waveguide structures combined a nonlinear material with a linear one. Mach-Zehnder interferometer (MZI) waveguide interferometer device has been developed for use of modulating, switching, and logic gates, etc. Most of them are operated by the principles of electric-optic effect where the change of refractive index in the arms of MZ interferometer is produced by applying the external electric field. In this paper, we propose and numerically investigate a novel nanoscale all-optical switch based on the local nonlinear metal-insulator-metal (MIM) plasmonic MZ interferometer waveguides. The Kerr nonlinear medium in the structure is changed by varying the pump light and the signal transmission can thus be controlled.

II. STRUCTURE AND THEORIES

As shown in Fig. 1(a), the MZI structure parameters are w=50nm, L_1=400nm, L_2=300nm. In Fig. 1(b) show of the transmission spectra without nonlinear medium, two side with nonlinear medium and single with nonlinear medium. The metal is assumed as silver, whose relative permittivity can be described by the well-known Drude model with (ε_∞, ω_p , γ) = (3.7, 1.38×10^{16}Hz, 2.73×10^{13}Hz) [4], where ε_∞ is the dielectric constant at the infinite frequency, γ and ω_p represent the electron collision frequency and bulk plasma frequency, respectively. The increased loss of silver in the nanostructure [5] is neglected and not involved in our simulations. The Kerr nonlinear material in arms of the Mach-Zehnder interferometer whose dielectric constant ε_f depends on the intensity of electric field $|E^2|$: $\varepsilon_f = \varepsilon_0 + \chi^{(3)}|E^2|$. The value of linear dielectric constant ε_0 is set as 2.0. The Kerr nonlinear material is assumed to be Ag-BaO, and its third-order nonlinear susceptibility is $\chi^{(3)} = 4.8\times10^{-10}$ [6]. The FDTD method is utilized to calculate the linear and nonlinear responses of our structure [7-9].



(a)



(b)

Fig.1 (a) The local nonlinear Mach-Zehnder interferometer based on MIM plasmonic waveguide structure. (b) Transmission spectra without nonlinear medium and single with nonlinear medium.

III. SIMULATION RESULTS

The structure of the proposed all-optical switch is shown in Fig. 1(a), which consists the metal claddings, the local nonlinear MIM plasmonic MZ interferometer waveguides. The parameters of the structure are w=50nm, L_1=400nm, L_2=300nm and the signal port intensity is $I_0=1\text{x}10^6\ V^2/m^2$. First, we change L_2 from 100nm to 350nm. The MZ interferometer waveguides of transmission spectra show in Figs. 2(a)-(f). According to the transmission spectra, we can see when the L_2=300nm is the best.When the signal port with the optical light intensity is $I_1=1.8\text{x}10^9\ V^2/m^2$. The transmission spectra show in Fig. 3(a). The output port is ON of the magnetic field distribution as shown in Fig. 3(b). The transmission efficiency at the wavelength 840nm is about 80%. The transmission spectra show in Fig. 3(c). The output port is OFF of the magnetic field distribution as shown in Fig. 3(d). The transmission efficiency at the wavelength 840nm is about 0%.

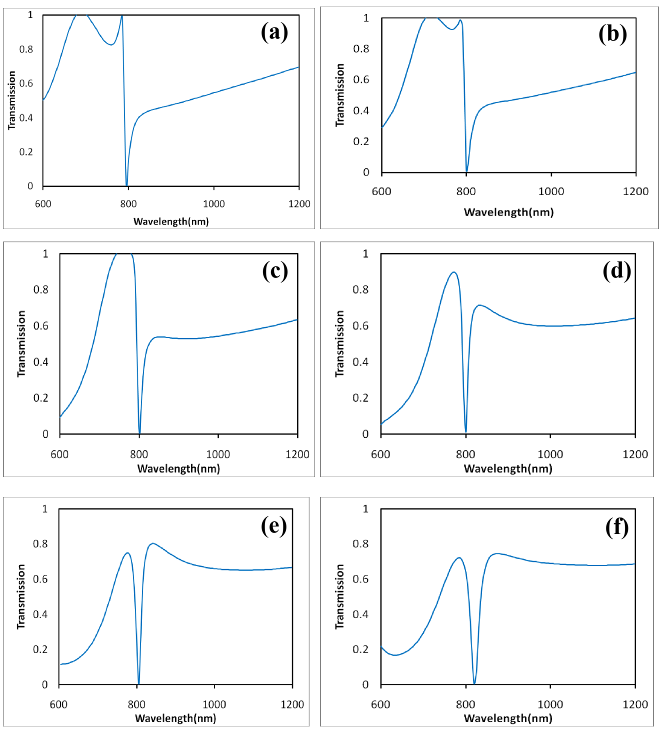


Fig.2 The transmission efficiencies of different L_2: 100nm to 350nm (a) 100nm (b) 150nm (c) 200nm (d) 250nm (e) 300nm (f) 350nm.

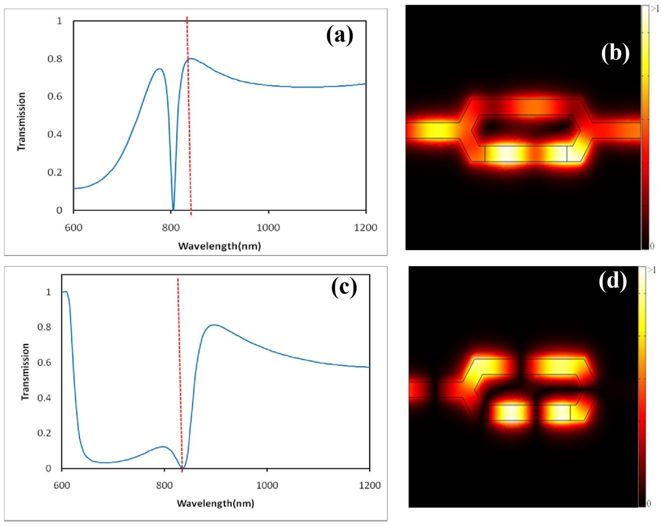


Fig.3 (a) The pump is $I_0=1\text{x}10^6\ V^2/m^2$ the transmission spectra, (b) The output port is ON of the magnetic field distribution, (c) The pump is $I_1=1.8\text{x}10^9\ V^2/m^2$ the transmission spectra, (d) and the magnetic field distribution of the OFF.

IV. CONCLUSION

We had successfully demonstrated the ultra compact all-optical switch based on the local nonlinear plasmonic Mach-Zehnder interferometer waveguide structure. The total size of the proposed switch is 0.86μ m × 0.8μ m. The transmission efficiency is about 80%. The numerical show that the proposed local nonlinear MIM plasmonic MZI waveguide structure could really function as an all-optical switch. It would be a potential key comment in the applications of all-optical signal processing systems.

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